The commercial fishery of the middle Nyong River, Cameroon: productivity and environmental threats

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Submitted 9 October 2008; accepted 6 July 2009.

ABSTRACT. Fishing methods, catches, fish species diversity, water quality and diets were examined in the middle Nyong River basin of south-central Cameroon over five years. Out of 79 indigenous species from the upper and middle Nyong in museum collections, 17 indigenous species added in this study (total = 100) and two feral alien species, only 38 are regularly captured by commercial fishers, and only 18 of these are sufficiently abundant and large enough to be of importance as food fish. Two of the most important are the alien *Oreochromis niloticus* and *Heterotis niloticus*. In the 2004/2005 season, fishers fished an average of 181 days per year, with a CPUE = 3.4 kg/fisher/day. Extrapolated, an estimated 37,000 fishers catch 24,500 t of fish per annum (24.6 kg/ha of watershed). Despite intensive sampling, 17 species previously reported for the Nyong, were not recaptured during this study. Most commercially important species, are detritus and/or aquatic arthropods feeders, with a high level of dietary overlap, but observed overlap between the most common commercial species and the introduced aliens is low. Although quantitative data are lacking on the state of the ecosystem at the time of earlier fish collections, there is circumstantial evidence that indigenous species may have suffered from competition with introduced aliens and/or changes in the ecosystem resulting from poor land use management and the use of pesticides in fishing.

KEYWORDS: Lower Guinea Rainforest, fish biodiversity, dietary overlap

INTRODUCTION

The Nyong River is in the Lower Guinea Equatorial Forest, one of the world's oldest and most biodiverse ecosystems, with about 500 species of fish (Brummett & Teugels 2004; Stiassney *et al*. 2007), 71% of which are endemic (Hugueny & Lévêque 1994). The Nyong flows 520 km west and south from its point of origin to the east of Abong-Mbang in the tropical rainforest of east-central Cameroon, discharging an annual average of 443 m^3/sec into the Gulf of Guinea at the small island fishing village of Behondo (Fig. 1). The headwaters lie very close to those of the Congo River Basin, and hence the two systems share a certain amount of biodiversity (Teugels & Guégan 1994). The major affluent streams to the Nyong are the rivers M'foumou (entering from the North) and So'o (entering from the South), both contributing to the river in its middle reaches. The basin covers approximately 27,800 km^2 between 2°48′ and 4°32′ N latitude and 9°54′ and 13°30′ E longitude (Hugueny 1989). The climate is transitional equatorial with one short (July-August) and one long (December-March) dry season alternating with rains (Fig. 2).

The Nyong is a typical "blackwater" river, with a mean pH of 6.2, hardness of <10 mg/l (as $CaCO_3$) and electrical conductivity between 20 and 30 µS/cm. Water temperature is always between 20 and 24° C. The water is naturally clear and tea-coloured as a result of the low dissolved nutrient concentration, low light (due to narrowness of valleys and canopy cover) and high tannin concentrations leaching from the large amount of allochthonous vegetative matter that falls or flushes into the water from the surrounding forest (Welcomme & de Merona 1988).

As for most of the Lower Guinea forest, there exists for the Nyong River little biological or ecological information, nor any sort of practical management plan that might track changes in the ecosystem. The Nyong Basin has already lost an estimated 46% of its primary forest to logging and conversion to agriculture and continues to lose forested watershed at an average rate of 7% per year (Revenga et al. 1998). Logging in Central Africa is undertaken in a largely irresponsible manner that alters stream courses and increases runoff and siltation. In addition, roads, sawmills and other infrastructure associated with logging attracts people into the forest, resulting in wholesale transformation of the ecosystem (Burns 1972; Garman & Moring 1993).

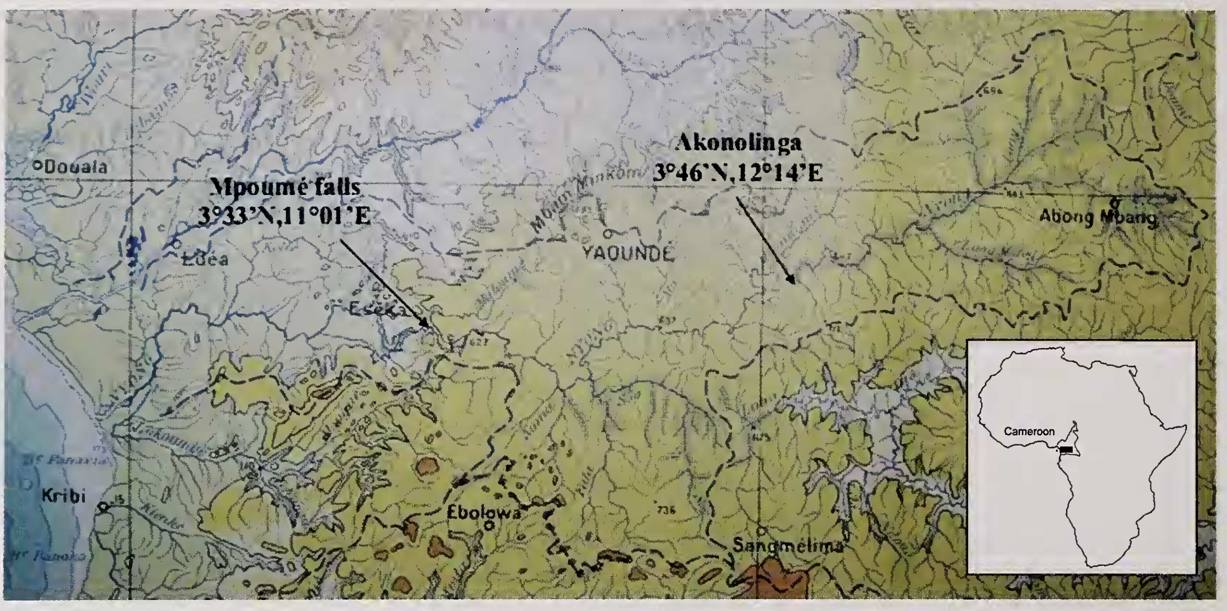


Fig. 1. Map of the Nyong River basin in Cameroon.

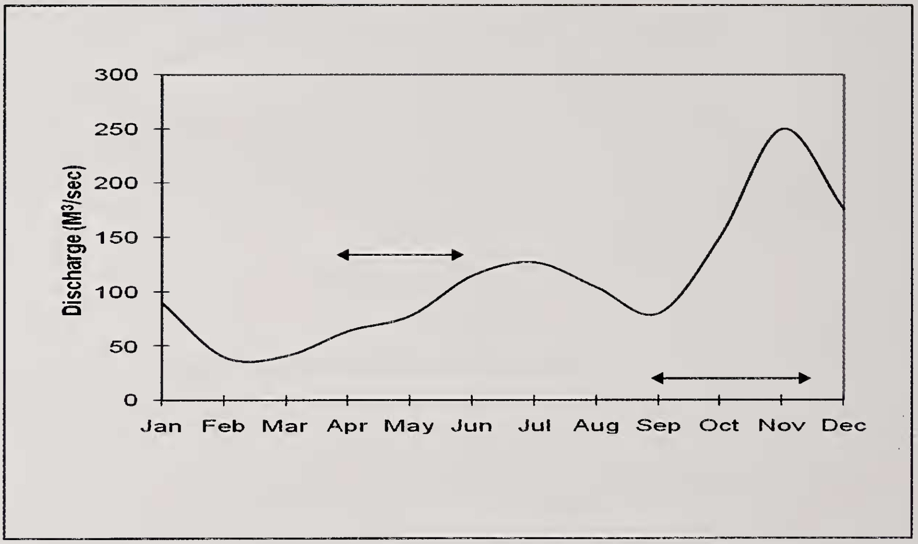


Fig. 2. Seasonal discharge of the middle Nyong River at Mbalmayo, indicating the reported timing of peak fishing (discharge data from SAGE 2003).

Improper use of agricultural pesticides has become widespread as a result of expanding small-scale oil palm cultivation, and is even used as a fishing method. Insecticides can be highly destructive of the entire food web and human deaths have been reported as a result of eating poisoned fish (du Feu 2001).

In addition, a number of alien species have been introduced, accidentally (by escape from aquaculture facilities) or on purpose to enhance capture fisheries, into the Nyong. These robust and aggressive species (*Oreochromis niloticus, Clarias gariepinus, Cyprinus carpio* and *Heterotis niloticus*) are highly invasive and could represent a serious threat to indigenous biodiversity.

To better understand the fishery and attempt to identify potential threats to this and other tropical rainforest rivers, a five-year study of fishing gears and techniques, fish diversity in commercial catches and the diets of both indigenous and introduced species was carried out on the middle Nyong River in southern Cameroon.

MATERIALS AND METHODS

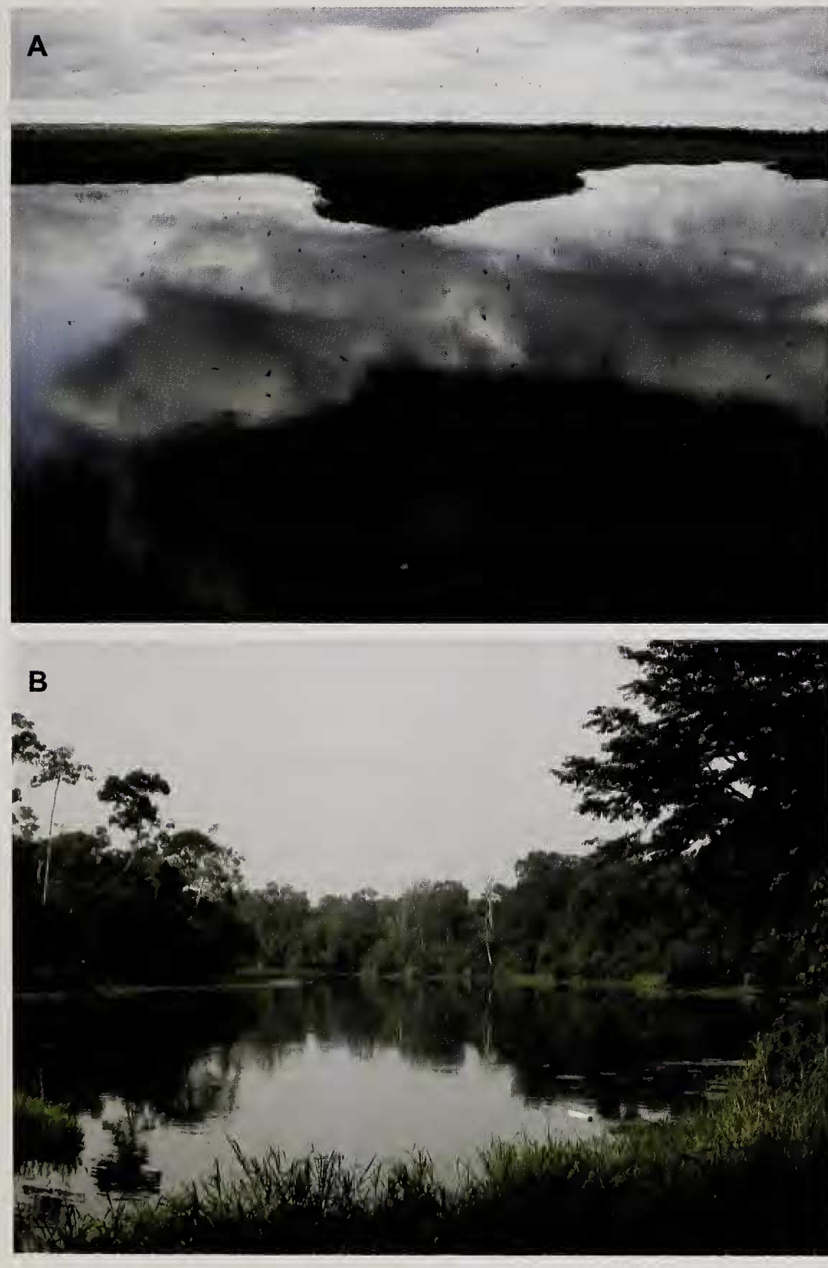
The section of the river here designated as the middle Nyong (Fig. 3b) is that part that passes through rainforest between the altitudes of 500 and 1000 m above MSL from a point about 10 km downstream

from Makak (3°33′ N, 11°01′ E) where the Mpoumé falls separate the middle from the lower reaches (Fig. 3c), up to Akonolinga (3°46′ N, 12°14′ E) above which the upper river occupies a large seasonal floodplain (Fig. 3a).

Monthly fish sampling was conducted between February 2001 and February 2006 at eight sites in the middle Nyong watershed: Akonolinga (3°46′ N, 12°14′ E), Anga'a (3°47′ N, 11°31′ E), Mbalmayo (3°30′ N, 11°30′ E), Pont So'o (3°19′ N, 11°29′ E), N'kol Ebae (3°19′ N, 11°26′E), N'tang (3°15′ N, 11°23′ E), Avèbe (03°20' N, 11°30' E) and Minlaba (3°11' N, 11°19' E). Samples consisting of at least five individuals each of all species available on each sampling date and at each sampling site were collected from commercial fishers, who employ a range of capture methods.

All samples were measured (TL) to the nearest mm, fixed in 95% ethanol and identified in the laboratory using Daget (1984), Vivien (1991), Mbega & Teugels (2003), Paugy *et al.* (2003), Geerinckx *et al.* (2004), Ng (2004) and Stiassny *et al.* (2007). Fishes that could not be identified from this literature were sent to the Belgian Royal Museum for Central Africa (MRAC) and/or the American Museum of Natural History (AMNH) for identification. Species regularly appearing in catches and marketed were deemed "commercial" while those occurring only infrequently and/or predominantly used for home consumption were considered by-catch.

To quantify the catch, a 13-month study (July 2004 – July 2005) was conducted among fishers in the villages of Pont So'o, N'kol Ebae, N'tang, Avèbe and Minlaba, which are representative of the majority of small fishing communities in the middle Nyong basin. Fishers in these villages exploit a number of rivers in the area, most importantly the Nyong, So'o, Fala, Bissi, Ossoe Koss, Soumou, Yenne, Nsono, N'tang Mebe Ossoe Beva'a, Akoumbegue, Ossoe Bissegué and Mimiteme. Of the 99 people reported by the local population to be fishing full-time in the area (Table 1), 27 agreed to participate in the creel survey and five (one from each village) volunteered as data collectors and were equipped with a spring balance and trained in completion of a basic survey form that captured data on weight and value of the catch by species.



During each sampling visit, visual observations were made of fishing activities, gears employed and the general condition of the river. Structured interviews were used to systematically collect information from fishers related to catch and environmental trends. In addition, measurements of temperature and dissolved oxygen were made with a Sentry III Oxygen/ Temperature Monitor, and water samples were collected for later measurement of electrical conductivity with a benchtop TPS 900C EC meter.

To quantify the natural diet of commercially important species,

Fig. 3. The upper Nyong River at Ayos in June (A), middle at Mbalmayo in March (B), and lower at Song Abwé in October (C). Photos: R E Brummett.

Table1. Number of households, fishers, fish traders and canoe builders in five typical fishing communities engaged in the commercial fishery of the middle Nyong River basin.

Village	Households (avg. pers.)	Full-time fishers Male	Female	Fish traders	Canoe builders
Pont So'o	9 (16.1)	37	4	28	3
N'tang	5 (8.0)	17	2	12	1
Avebe	6 (11.7)	9	0	17	2
N'kol Ebae	7 (10)	18	7	10	0
Minlaba	8 (12.3)	9	3	0	0
Total	**35 (11.7)**	**83**	**16**	**67**	**6**

stomachs of 24 individuals (two fish of each species per month between February 2001 and February 2002) were dissected and fixed in 10% formalin. For species with no true stomach (e.g. *Labeo lukulae*) the upper 5 cm of the digestive tract was taken. Stomach contents were analysed according to the frequency of occurrence method described by Hyslop (1980) and Bowen (1983). Ingested items were classified as detritus, plant material, insects (both adult and larval forms), aquatic crustaceans (primarily *Macrobrachium* spp) or fish. Data were recorded as a percentage of full stomachs containing one or more item from each food category represented. Statistica 4.5 (1993) software was used to perform cluster analysis to identify major food groups. The Schoener index (SI) (Schoener 1974) was used as an indicator of dietary overlap among species.

RESULTS AND DISCUSSION

The middle Nyong river is special in Cameroon for two important reasons: 1) Unlike the big coastal and larger river fisheries on the Sanaga and Benue Rivers which are dominated by foreign commercial fishers, predominantly from Mali and Nigeria, the middle Nyong river fishery is a traditional subsistence fishery operated by the indigenous population; and, 2) much of the southern portion of the middle Nyong basin (where our sampling was concentrated) drains seasonal swampforest, a critical spawning habitat for many rainforest river fishes.

Table 2. List of known indigenous species in the Nyong River (excluding those with marine affinity). Fish captured in this study are shown in bold font. Fish species not captured, but reported in the reference collections of the Royal Museum for Central Africa (RMAC), Tervuren, Belgium and/or the Muséum National de l'Histoire Naturelle, Paris or FishBase (2004) are shown in normal font. Species one would expect to have collected, but which did not appear in our samples are indicated with a question mark (?).

Alestes macrophthalmus	***Mastacembelus cryptacanthus***
Amphilius longirostris	*Mastacembelus niger*
Anaspidoglanis macrostoma	***Microctenopoma nanum***
Aphyosemion ahli	*Micropanchax camerunensis*
Aphyosemion bivittatum	***Microsynodontis batesii***
Aphyosemion cameronense	*Mormyrops anguilloides* ?
Aphyosemion exiguum	*Mormyrops caballus* ?
Aphyosemion loennbergii	***Mormyrus tapirus***
Aphyosemion splendopleure	*Nannaethiops unitaeniatus*
Barbus aspilus	*Nannocharax intermedius*
Barbus brazzai	***Nannocharax cf. rubrolabiatus***
Barbus camptacanthus	***Neolebias trewavasae***
Barbus guirali	*Neolebias unifasciatus*
Barbus holotaenia ?	***Opsaridium ubangiense***
Barbus jae	***Parailia occidentalis***
Barbus martorelli	***Parachanna obscura***
Benitochromis batesii	***Paramormyrops kingsleyae***
Bostrychus africanus	**Paramormyrops curvifrons**
Brienomyrus brachyistius	***Parananochromis « N'tem »***
Brycinus kingsleyae	***Parauchenoglanis altipinnis***
Brycinus longipinnis	***Parauchenoglanis balayi***
Brycinus macrolepidotus	***Parauchenoglanis longiceps***
Brycinus nurse	*Pelvicachromis taeniatus*
Bryconaethiops microstoma ?	*Petrocephalus christyi* ?
Chiloglanis cameronensis	***Petrocephalus microphthalmus***
Chrysichthys auratus	***Petrocephalus simus***
Chrysichthys nigrodigitatus	*Phenacogrammus major*
Chrysichthys nyongensis ?	***Phractura longicauda***
Clariallabes longicauda	*Procatopus similis*
Clarias camerunensis	*Prolabeops nyongensis*
Clarias jaensis	***Raiamas batesii***
Clarias longior ?	***Raiamas buchholzi***
Clarias pachynema	*Sarotherodon galilaeus sanagaensis* ?
Ctenopoma maculatum	***Sarotherodon mvogoi***
Distichodus notospilus	*Schilbe brevianalis*
Doumea « Cameroon »	*Schilbe grenfelli* ?
Epiplatys sangmelinensis	***Schilbe intermedius***
Epiplatys sexfasciatus	***Schilbe multitaeniatus***
Hemichromis elongatus	*Schilbe nyongensis* ?
Hemigrammocharax ocellicauda	***Synodontis batesii***
Hepsetus odoe	***Synotontis marmoratus***
Kribia kribensis	***Synodontis rebelilobesus***
Kribia nana	***Synodontis steindachneri***
Labeo annectens ?	*Synodontis tessmanni* ?
Labeo lukulae	***Tilapia margaritacea***
Labeobarbus rocadasi	*Tilapia mariae* ?
Labeobarbus batesii ?	***Tilapia nyongana***
Labeobarbus micronema ?	***Varicorhinus sandersi***
Malapterurus electricus	*Varicorhinus tornieri* ?
Marcusenius moorii	*Varicorhinus werneri* ?

Table 3. Fishing techniques and the species they target in the middle Nyong River, Cameroon.

Technique	Description	Targeted Species
Filet Cablé	Comprised of three layers of gill net of differing mesh sizes; an active gear resembling a trammel net but fished like a seine by groups of 4-5 fishers.	*Heterotis niloticus*
Gill Nets	12 to several hundred meters in length, 4 m depth and mesh sizes of 30-60 mm. Installed more or less permanently parallel to river banks and checked periodically.	Mormyrids, Alestids
Nlop Mekwel Mekos	Two baited hooks attached on short lines to the center of a pole, which is wedged in the weeds across routes frequented by fish.	*Parachanna obscura*
Adsegneng	A cane pole with appx. 30 cm of line and a size 13/14 hook (usually baited with soap), jammed into a mud bank overnight.	*Clarias, Schilbe*
Élong	Size 14/15 baited hook on a weighted 6-10 m line thrown into the river and anchored to the bank or to overhanging branches	Large Cyprinids, Catfish
Ôngaè	Up to 50 m hook line with hooks every 2 m baited with crab claws and strung from bank to bank or from the bank to a large mid-water boulder.	Large *Barbus*
Méfog	A baited size 13/14 hook on 1-2m of line attached to a cane pole, fished by wading along the bank and flicking the baited hook under cut banks or into holes.	*Clarias*
Agara	A long (2.5m) version of Méfog used in rapids.	*Schilbe*
Nlop Bekara	Manioc attached to a cord, left overnight among boulders near rapids.	Crabs
Mbere	A weighted line attached to a wooden float with a worm-baited hook on 30 cm trailer.	All species, esp. *Parauchenoglanis*
Bap	Cane pole with a baited hook, mostly used by children.	*Opsaridium, Brycinus, Barbus, Petrocephalus, Schilbe*
Nsong	A large open-ended basket installed in fast water; facing upstream, fish are captured and held in place by water pressure.	Small individuals of all species
Aya	Basket trap made of reeds or bamboo with a conical entrance, anchored in low order tributaries by women to supplement household food supplies.	*Macrobrachium*, crabs, Misc. small fishes
Nkoé	A larger, longer version of Aya baited with manioc.	Crabs
N'dayirga	Pole with a baited hook on a trailer jammed into bottom in stagnant water.	*Clarias*
N'touk	A garden basket with worms or other bait attached to the interior and lowered into still water at night. When fish are felt bumping around, the basket is slowly raised.	*Clarias*
Ebam	Handline with multiple small hooks and weighted with a stone to facilitate casting.	Mormyrids
Alok	Small earthen dams across low order forest streams. Several dams are constructed in series, effectively blocking water flow. Women then bucket out any remaining water, catching the fish by hand or with the help of baskets.	Smaller individuals + small species, esp. *Barbus, Paramormyrops, Clarias*
Alam	Dam constructed of branches and boulders, with a chute in which fish are trapped as waters rise and recede in the rainy seasons (Figure 4). Used exclusively in the So'o watershed.	Most species, esp. *H. niloticus, mormyrids, Raimas*

Species Diversity

In total, 15 families, 38 genera and 56 indigenous species were recorded (Table 2). Of these, only 18 (including two alien species, *Heterotis niloticus* and *Orochromis niloticus*) are currently important in the commercial catch. *H. niloticus* and *O. niloticus* are indigenous to the Niger River and Lake Chad basins and were stocked and/or escaped from aquaculture facilities in the Nyong watershed in the late 1950s and early 1960s and have since become established (Depierre & Vivien 1977; Welcomme 1988).

Hugueny (1989) reported 79 exclusively freshwater species in the collections of the MRAC, the French Muséum National d'Histoire Naturelle (MNHN) and the Natural History Museum, London (BMNH). On the list of Nyong River species held at the MRAC alone there are 64 species (Jos Snoeks, MRAC, pers. comm., Jan. 2004). At the MNHN in Paris, there are an additional 15 species not on the MRAC list, making a total of 79 (D. Paugy, MNHN, personal communication, October 2005). In contrast, Teugels & Guégan (1994) recorded 107 species. Although Teugels and Guégan did not present a list of species, a large part of the difference in count is probably due to their inclusion of euryhaline fishes, which can make up as much as 20–50% of the fish fauna in the lower reaches of African coastal rivers (Djama 2001; Teugels, Reid & King 1992). In a brief visit made to the lower Nyong in May 2005, representatives of several typically marine families, i.e. Carangidae, Clupeidae, Cynoglossidae, Haemulidae, Lutjanidae, Polynemidae, Sciaenidae and Scombridae were collected from fishers' catches.

Of the 83 species on the MRAC and MNHN lists, 38 were recaptured in 2001–2006 (Table 2). In addition, 17 species captured in 2001–2006 were not previously on the list (*Alestes macrophthalmus, Bostrychus africanus, Brycinus longipinnis, Brycinus nurse, Chrysichthys auratus, Distichodus notospilus, Doumea* "Cameroon", *Mastacembelus cryptacanthus, Microsynodontis batesii, Nannocharax* cf *rubrolabiatus, Parailia occidentalis, Paramormyrops curvifrons, Parananochromis* "Ntem", *Phractura longicauda, Schilbe intermedius, Synodontis marmoratus & Varicorhinus sandersi*) bringing the total to 96. Including the two aliens, the current list includes 98 species.

Every effort, including visits to MNHN, MRAC and the AMNH and extensive consultations with other taxonomists, was made to update and correct taxonomic errors and changes on the list. Four errors (*Micralestes humilis, Paramormyrops sphekodes, Parananochromis caudifasciatus* and *Parauchenoglanis guttatus*) were found on the original lists (Stiassny et al. 2007), and considering the uncertainty surrounding the fish fauna of the region others undoubtedly persist. Nevertheless, there remains a substantial discrepancy between the species caught in the 2001–2006 survey and those reported to be in the river by earlier observers.

As the principal method of sampling was based on the gears used in the commercial fishery, it could be that gear selectivity accounts for some of this discrepancy. Fishers tend to concentrate their effort on the main river and do not target very small species. Although a number of smaller and rarer species were taken, of the

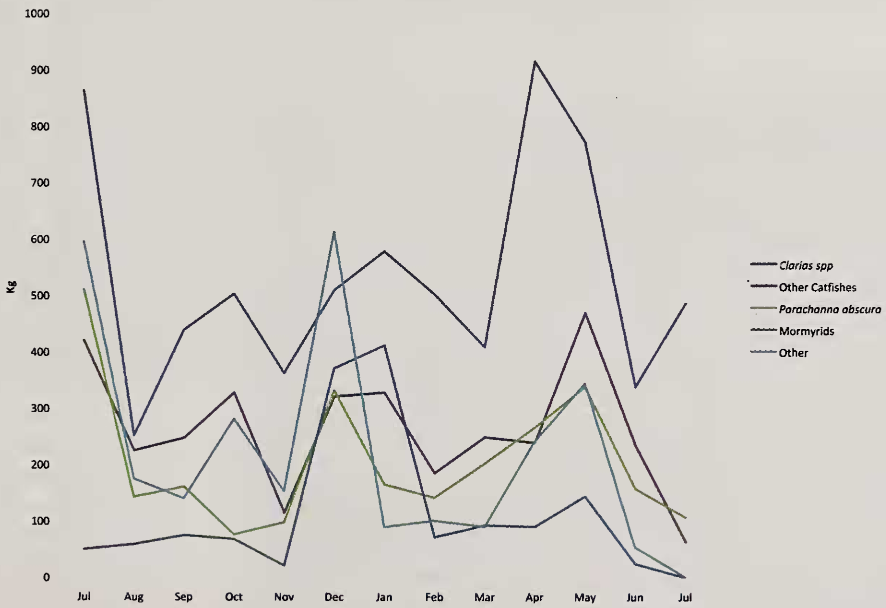


Fig. 4. Monthly catch by species group in five villages of the Middle Nyong River Basin in 2004/2005.

fish on the combined list (Table 2) that were not caught in 2001–2006, 25 species seldom exceed 10 cm in total length and were generally unknown to local fishers interviewed and shown photographs. In addition, reclusive or predominantly swamp species such as *Malapterurus electricus* and *Mastacembelus niger* might be expected to be infrequently captured in a fishery focused on the main river channels. However, sampling intensity or gears alone cannot explain why some species were not recaptured, as many of the missing species are very similar in size and shape to the species that were captured and 17 extra species were added to those on the earlier lists.

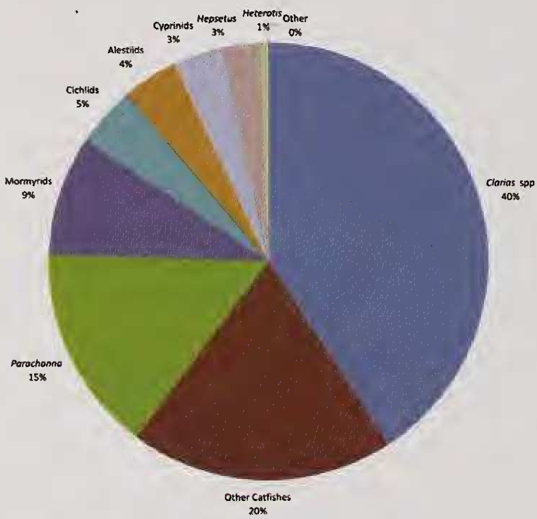


Fig. 5. Catch composition from a survey of five villages in the middle Nyong River basin in 2004/2005).

THE FISHERY

The main gears used in the middle Nyong basin are shown in Table 3. The large amount of allochthonous wood and boulders in the streambed constrains the use of active fishing gears. Traditional indigenous methods rely on dams, basket traps and various hook-lines. Gill-nets, introduced more recently, are the dominant gear used by full-time fishers.

Fishers can be differentiated as professional/ full-time (most of whom are Malians based in the towns of Mbalmayo and Akonolinga and who target *Heterotis niloticus*) or seasonal fishers. The majority are seasonal, fishing as part of a diverse livelihood strategy that includes hunting, small livestock and both cash and food crops. Of the 27 fishers participating in the 2004/2005 catch survey, seven (26%) were full-time and the rest were seasonal. On average, fishers fish about 181 days per year (full-time fishers fish about 288 days each, while seasonal fishers fish about 144 days), capturing an average of 614 kg of fish (Fig. 4). Catch per unit of effort (CPUE) in the area sampled is thus 3.4 kg/fisher/fishing day. Average village selling price for fresh fish is fcfa 500 per kg (approximately US$ 2.00 in 2007); fishing households thus gross an average of something on the order of fcfa 1.37 million annually from fishing (including household consumption, not measured in this study), compared to the Cameroonian average gross income of fcfa 585,000 reported by the World Bank in 2006 (http://devdata.worldbank.org/AAG/cmr_aag.pdf).

Leaving out the large urban centers of Mbalmayo and Yaoundé, the population density in the middle Nyong Basin is estimated at 17 persons per km^2

Fig. 6. A fish dam, or alam, constructed on the Fala River, a tributary of the So'o in the central Nyong watershed. Fish migrating upstream to spawn pass over the dam which is submerged at high water. As water levels drop, adult fish returning from the spawning grounds are trapped, while smaller individuals pass through. Inset shows a detail of the chute where fish are stranded. (Photo: R E Brummett.)

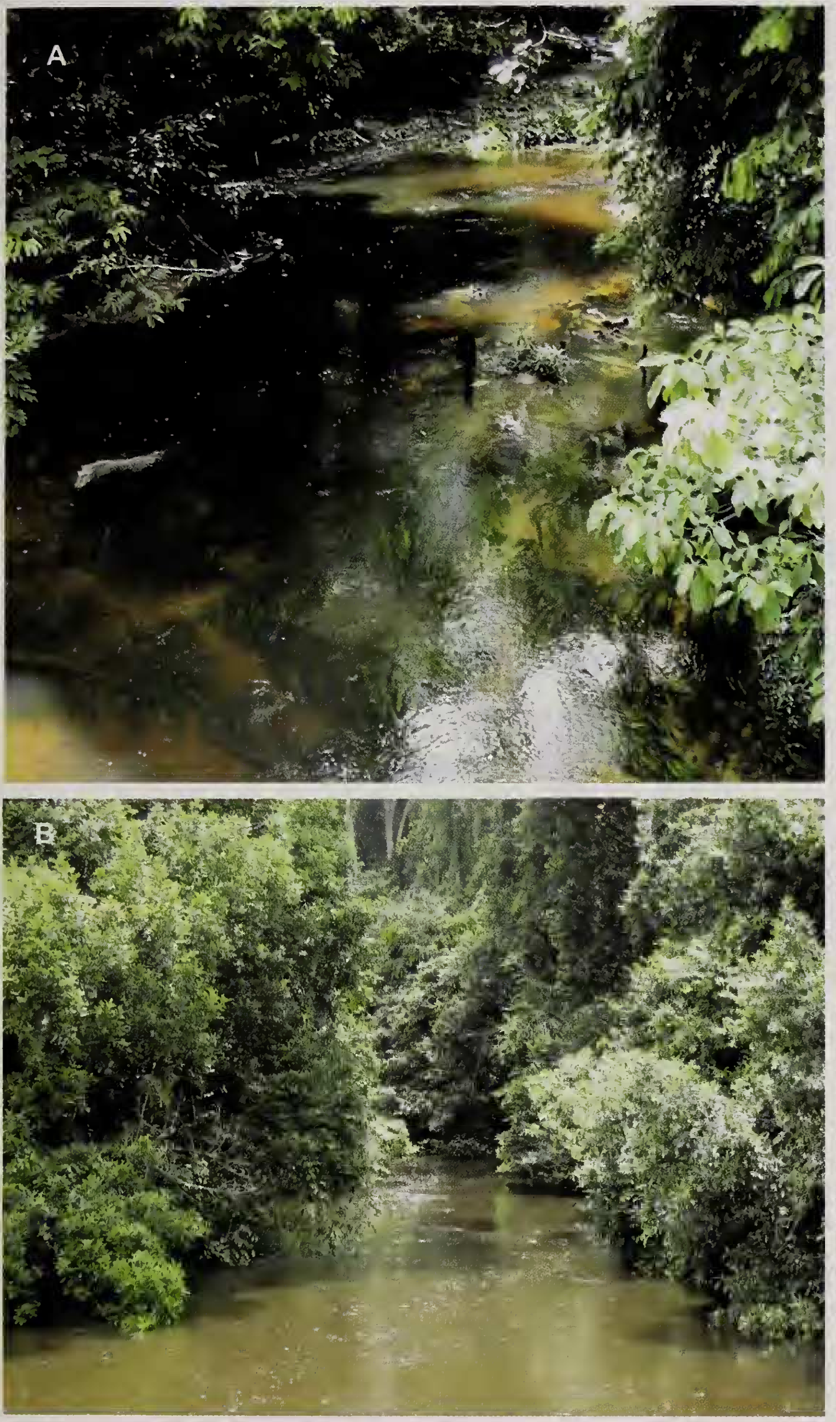


Fig. 7. Seasonal variation in water clarity in the Nyong River basin. During the dry season (A), water is clear. Following rains (B) exposure of soil in the watershed due to logging, farming and associated road construction results in increased silt loads. (Photo: R E Brummett.)

(Essama-Nssah & Gockowski 2000) spread over 10,300 km^2 (37% of the entire Nyong basin). If fishing practices in the five villages and catches in the 2004/2005 survey can be considered representative, about 40,000 full-time fishers catch an estimated 24,500 t of fish per annum from the middle Nyong River fishery (2.5 t/km^2 or 25 kg/ha of watershed), somewhat higher than catches of 16 kg/ha of watershed in the upper Cross River, a system similar to the Nyong, estimated from a frame survey conducted in October-December 2000 (Mdaihli *et al.* 2003).

The main fishing season is from September through December when river levels are increasing (Fig. 2) and many species are undertaking upstream migrations into flooded swampforest to spawn (Munro *et al.* 1990). A second peak occurs in April/May. A total of 25 species were recorded in the professional catch, the bulk of the catch is clariid catfishes and *Parachanna obscura* (Fig.

Table 4. Percentage occurrence of different food items in the stomachs of 18 species of fish most commonly captured in the Nyong River, Cameroon (TL = Total Length ± Standard Deviation).

	Brycinus macrolepidotus	*Brycinus kingsleyae*	*Hemichromis elongatus*	*Oreochromis niloticus*	*Clarias camerunensis*	*Chrysichthys nigrodigitatus*	*Anaspidoglanis macrostoma*	*Parauchenoglanis longiceps*	*Labeo lukulae*
Number Stomachs	10	140	14	10	10	33	10	10	112
Full stomachs	8	105	9	10	10	10	6	10	32
TL Range (mm)	240-330	111-155	123-145	180-326	199-370	162-305	210-300	224-315	235-340
TL Average ± SD	279.2 ± 45.8	138.1 ± 6.0	137.6 ± 8.4	224 ± 46.2	257 ± 21.4	237.1 ± 36.3	253.8 ± 36.8	285.6 ± 25.4	292.7 ± 24.6
Detritus	-	11	-	100	100	100	-	-	16
Plant Material	-	-	-	40	-	-	-	-	100*
Insects	75	56	67	12	100	90	75.0	86	-
Aquatic Crustacea	50	51	-	3	83	-	100	43	-
Fish	-	-	70	-	-	-	10	14	-

* *L. lukulae* stomachs contained mostly epiphytic algae grazed from submerged surfaces.

	Raimas batesii	*Hepsetus odoe*	*Brienomyrus brachyistius*	*Marcusenius moorii*	*Mormyrus tapirus*	*Parachanna obscura*	*Petrocephalus simus*	*Heterotis niloticus*	*Schilbe intermedius*
Number Stomachs	10	16	10	54	10	21	121	65	22
Full stomachs	8	4	10	35	10	13	73	15	10
TL Range (mm)	191-235	257-300	130-140	142-217	393-405	238-399	70-95	210-800	192-263
TL Average ± SD	213.6±24.9	274.4 ± 13.1	135.0 ± 7.1	154.5 ± 36.7	400.0 ± 6.2	296 ± 23.1	81.3 ± 4.3	578.2 ± 196.5	231.0 ± 21.5
Detritus	-	-	50	86	100	-	17.1	100	80
Plant Material	-	-	-	-	-	-	-	100	-
Insects	100	-	100	69	100	34	100	27	50
Aquatic Crustacea	-	-	27	14	80	-	12	7	-
Fish	47	100	-	-	-	100	-	-	-

5).

Fishers reported that catches have remained more or less steady over recent years, in some cases actually increasing with the availability of gill netting and fish hooks. Although not yet having a major impact on the fish catches of the villages sampled in the middle Nyong, fishers more generally report a gradual shift in emphasis from indigenous species to the introduced *O. niloticus* and *H. niloticus* since their introduction at Akonolinga in the early 1960s (Depierre &Vivien 1977; Abina 2005).

Missing Species

Despite gear selectivity, 17 species were not captured in 2001-2006 although they reach commercial sizes and are found in the same habitats as those species which were captured. These include species of *Clarias, Chrysichthys, Labeo, Labeobarbus, Mormyrops, Parauchenoglanis, Sarotherodon, Schilbe, Synodontis* and *Varicorhinus*, some of which reach sizes of >50 cm and weights >10 kg and which were previously reported as important components of the fishery by Depierre & Vivien (1977). When presented with a list and photos of the missing species, fishers reported that *Labeo annectens, Labeobarbus batesii, Labeobarbus micronema* and *Synodontis rebeli* in particular were much more common in the past. During August (one of the peak fishing seasons) of 2006, a two-week expedition of eight fishers and two of the authors fished the area between the confluence of the So'o River and the town of Mbalmayo specifically to capture the missing species. Using every traditional fishing method shown in Table 2, *Barbus guirali, Clariallabes longicauda* and *Paramormyrops curvifrons*, previously missing, were added to the list, but none of the other missing species were captured.

In recent years, substantial habitat modification associated with rural development in the Nyong Basin, could have affected species which were once abundant (Abina 2005). Observation of the Nyong

Table 5. Schoener index (SI) of dietary overlap for 18 commercially important fish species from the Nyong River, Cameroon. Values for the introduced alien species *Oreochromis niloticus* (4) and *Heterotis niloticus* (17) are in bold font. 1 = *Brycinus macrolepidotus*, 2 = *Brycinus kingsleyae*, 3 = *Hemichromis elongates*, 4 = *Oreochromis niloticus*, 5 = *Clarias camerunensis*, 6 = *Chrysichthys nigrodigitatus*, 7 = *Anaspidoglanis macrostoma*, 8 = *Parauchenoglanis longiceps*, 9 = *Labeo lukulae*, 10 = *Raimas batesii*, 11 = *Hepsetus odoe*, 12 = *Brienomyrus brachyistius*, 13 = *Marcusenius moorii*, 14 = *Mormyrus tapirus*, 15 = *Parachanna obscura*, 16 = *Petrocephalus simus*, 17 = *Heterotis niloticus*, 18 = *Schilbe intermedius*.

Fish	1	2	3	**4**	5	6	7	8	9	10	11	12	13	14	15	16	**17**	18
1		0.85	0.36	**0.25**	0.21	0.68	0.70	0.84	0.21	0.40	0.13	0.51	0.36	0.17	0.06	0.33	**0.46**	0.98
2	0.85		0.64	**0.45**	0.59	0.77	0.78	0.84	0.47	0.62	0.46	0.73	0.69	0.56	0.55	0.64	**0.35**	0.91
3	0.36	0.64		**0.33**	0.29	0.52	0.58	0.71	0.37	0.86	0.76	0.55	0.57	0.47	0.68	0.54	**0.21**	0.67
4	0.25	0.45	0.33		0.48	0.21	0.23	0.33	0.60	0.31	0.36	0.50	0.70	0.67	0.30	0.59	**0.80**	0.36
5	0.21	0.59	0.29	**0.48**		0.68	0.62	0.58	0.08	0.43	0.04	0.74	0.72	0.81	0.14	0.75	**0.38**	0.62
6	0.68	0.77	0.52	**0.21**	0.68		0.94	0.81	0.24	0.61	0.28	0.67	0.52	0.50	0.37	0.58	**0.11**	0.85
7	0.70	0.78	0.58	**0.23**	0.62	0.94		0.82	0.25	0.60	0.34	0.61	0.53	0.43	0.43	0.52	**0.12**	0.84
8	0.84	0.84	0.71	**0.33**	0.58	0.81	0.82		0.35	0.78	0.46	0.77	0.64	0.59	0.56	0.68	**0.23**	0.93
9	0.21	0.47	0.37	**0.60**	0.08	0.24	0.25	0.35		0.34	0.46	0.35	0.37	0.27	0.37	0.33	**0.71**	0.39
10	0.40	0.62	0.86	**0.31**	0.43	0.61	0.60	0.78	0.34		0.62	0.69	0.56	0.62	0.54	0.68	**0.19**	0.71
11	0.13	0.46	0.76	**0.36**	0.04	0.28	0.34	0.46	0.46	0.62		0.31	0.33	0.23	0.91	0.29	**0.17**	0.43
12	0.51	0.73	0.55	**0.50**	0.74	0.67	0.61	0.77	0.35	0.69	0.31		0.80	0.83	0.37	0.91	**0.39**	0.77
13	0.36	0.69	0.57	**0.70**	0.72	0.52	0.53	0.64	0.37	0.56	0.33	0.80		0.87	0.32	0.88	**0.59**	0.67
14	0.17	0.56	0.47	**0.67**	0.81	0.50	0.43	0.59	0.27	0.62	0.23	0.83	0.87		0.19	0.92	**0.57**	0.60
15	0.06	0.55	0.68	**0.30**	0.14	0.37	0.43	0.56	0.37	0.54	0.91	0.37	0.32	0.19		0.28	**0.12**	0.52
16	0.33	0.64	0.54	**0.59**	0.75	0.58	0.52	0.68	0.33	0.68	0.29	0.91	0.88	0.92	0.28		**0.48**	0.68
17	0.46	0.35	0.21	**0.80**	0.38	0.11	0.12	0.23	0.71	0.19	0.17	0.39	0.59	0.57	0.12	0.48		0.26
18	0.98	0.91	0.67	**0.36**	0.62	0.85	0.84	0.93	0.39	0.71	0.43	0.77	0.67	0.60	0.52	0.68	**0.26**	
Avg.	0.44	0.64	0.54	**0.44**	0.48	0.55	0.55	0.64	0.36	0.56	0.39	0.62	0.60	0.55	0.39	0.59	**0.36**	0.66

River during sampling revealed periodic substantial declines in water quality, especially increasing sediment loads, as a result of human activities in the forest (Fig. 7). These declines are particularly severe when some of the most commercially important species are, according to the fishers, undertaking reproductive migrations: early in the rainy seasons of March-June (*Brycinus, Chrysichthys, Labeo, Labeobarbus, Marcusenius*) and September-November (*Brienomyrus, Petrocephalus*). According to Munro *et al.* (1990), *Schilbe, Synodontis, Clarias, Distichodus* and *Alestes* are other important species reported to spawn in the wet seasons and may thus be vulnerable to sedimentation during early life stages. In undisturbed sites, water was clear brown with a mean temperature of 23.5°, dissolved oxygen between 4.2 and 6.5 mg/L (measured at noon) and electrical conductivity between 20 and 30 µS/cm. In sites affected by logging, the water was cloudy to muddy with a mean temperature of 27°, dissolved oxygen of <2.0 mg/L and average electrical conductivity of 48 µS/cm.

The use of pesticides such as Lindane, Thiosulfan 359 and Gammalin 20 for agriculture and fishing is widespread in the middle Nyong basin. These chemicals kill virtually all aquatic fauna to a depth of several centimetres into the mud and have long-lasting negative effects on fish diversity (du Feu 2001). Fishers report that stream sections fished with poisons may remain devoid of fish for up to 20 years.

In 1958, 20 fingerling *Heterotis niloticus* were introduced by the Cameroonian Forestry Service to the Nyong at Akonolinga in an effort to establish a commercial fishery (Depierre & Vivien 1977). In 1976, Depierre & Vivien estimated 60 t of *H. niloticus* captured in the vicinity of Ayos in the upper Nyong. Mengang (1984) estimated the *H. niloticus* catch landed at Akonolinga at 616 t/year. Abina (2005) calculated that *Oreochromis niloticus* accidentally introduced into the river from flooded government fish ponds, also at Akonolinga, now represents 12.5% of the total catch in the upper Nyong basin. As their populations continue to expand downstream, the introduced *O. niloticus* and *H. niloticus* could be expected to displace indigenous species (Lever 1996). In addition, after the end of formal sampling, fishers in Pont So'o captured a species they had never seen before, which upon inspection was identified as *Claris gariepinus*, another introduced species. Kamdem-Toham & Teugels (1998, 1999) and Mdaihli *et al.* (2003) showed how the collective impact of introduced species, increased turbidity and the poisoning of streams have altered the ecological structure of the Cross and N'tem Rivers in Southern and SE Cameroon, and it seems likely such changes may likewise be negatively affecting the Nyong River.

Dietary Characterisation

Fish diets (Table 4) reflect the food resources of the rainforest river environment. Low light and alkalinity limit the growth of phytoplankton, upon which many

tropical ecosystems rely as the basis of the food web (Delincé 1992). The main nutrient inputs to rainforest rivers such as the Nyong, are comprised mainly of leaves and other plant materials that fall or are flushed in during rain or flooding events (Welcomme & de Merona 1988). The nutritional value of these decaying plant materials derives primarily from the protozoa and bacteria that colonise them (Anderson 1987, Moriarty 1987) and insects (primarily larval forms) and crustacean (primarily *Macrobrachium* spp) shredders and grazers that are in turn consumed by fishes (Wolfgang Junk, Max Plank Institute of Limnology, pers. comm., February 2003).

Cluster analysis identified four groups, based on diet. Group A (*Brycinus macrolepidotus, Brycinus kingsleyae, Chrysichthys nigrodigitatus, Anaspidoglanis macrostoma, Parauchenoglanis longiceps* & *Schilbe intermedius*) eat mostly insects and/or aquatic crustacea. Group B (*Clarias, camerunensis, Brienomyrus brachyistius, Marcusenius moorii, Mormyrus tapirus* & *Petrocephalus simus*) target insects and crustaceans as well, but include a larger proportion of detritus in the diet. Group C (*Hemichromis elongatus, Raimas batesii, Hepsetus odoe & Parachanna obscura*) are largely piscivores. Group D (*Oreochromis niloticus, Labeo lukulae* & *Heterotis niloticus*) depend heavily on detritus and aquatic plants.

Dietary overlap (Table 5) among species was significant, with 10 of 18 species having an average SI of at least the 0.6 considered as biologically significant (Wallace & Ramsey 1983). Insects and aquatic crustacea were the most often targeted food items overall, and those species that depend heavily on these groups showed the highest degrees of dietary overlap.

The large degree of feeding niche overlap among species is consistent with the findings of Matthes (1964) who studied the middle Congo River and Hickley & Bailey (1987) working on the Nile in Sudan. Fish can use spatial and/or temporal partitioning to minimise competition both among species and age-classes (Matthes 1964; Kandem-Toham & Teugels 1997; Brummett 2000). Although detailed behavioural and ecological niche data are unavailable, the relatively high indigenous biodiversity of rainforest rivers (Teugels & Guégan 1994), their antiquity (Maley 1987; Schwartz 1991) and the high level of dietary overlap, imply a complex of behaviours regulating and balancing the ecosystem.

The relatively low degree of dietary overlap between the introduced *H. niloticus* and *O. niloticus* and indigenous species implies that these aliens are either taking advantage of an underutilised niche, or have already eliminated those species with which they compete. Without dietary data on the missing species, it is premature to assume that such wholesale reduction in species diversity as is being witnessed in the Nyong River could be attributed exclusively to dietary competition with the introduced *O. niloticus* and *H. niloticus*, but some effect cannot be ruled out. Indeed, the detritus/plant diet of the indigenous *L. lukulae* significantly overlaps with only these two species and *L. lukulae* is one of the species reported by fishers to be in decline. Of the other genera also specifically reported to be decreasing in abundance, *Clarias, Chrysichthys, Labeo, Labeobarbus, Mormyrops, Parauchenoglanis, Sarotherodon, Schilbe, Synodontis* and *Varicorhinus* have all been reported to rely heavily on detritus and/or plant material as major components of the diet (Matthes 1964; Seegers 1996). Cases of competition for food having negative impacts on indigenous species have been observed elsewhere (Declerck *et al.* 2002) and although little is known of the ecological impacts of *H. niloticus* introductions, cases of competition for food among indigenous fishes and *O. niloticus* resulting in declines in the former have been widely reported (Lever 1996).

Depierre & Vivien in 1977 estimated the annual catch of *H. niloticus* at 1 t/fisher, for an average productivity of 150 kg/ha of water surface area in the upper Nyong (a floodplain). Catches in the Cross River basin, a similar rainforest river ecosystem to the Nyong, are about 16 kg/ha watershed (Mdaihli et al. 2003) and it seems unlikely that the reported quantity of introduced fish could be growing in the river without affecting the food web and indigenous species in some way.

CONCLUSIONS

Significant changes in the Nyong River basin over the last 20 years include localised deforestation, expanding slash-and-burn agriculture, widespread use of illegal chemical fishing and the introduction of alien fish species. Without quantitative data on pre-existing conditions and fish abundance, it is impossible to say for certain that these changes have resulted in the declines in indigenous species reported by local fishers. Nevertheless, the inability of researchers to recapture many once-common species indicates that some negative changes have occurred. Similar ecological disturbances elsewhere have resulted in similar declines in indigenous species, thus it seems likely that recent changes in the Nyong River basin have had a significant negative impact on aquatic biodiversity.

ACKNOWLEDGEMENTS

This work was co-funded by the WorldFish Center and the British Department for International Development through their Development of Integrated Aquaculture Systems for Smallscale Farmers in the Forest Margins of Cameroon project NRE9800 605/522/003. Special thanks to Jos Snoeks, Dominique Adriaens, Emmanuel Vreven and the late Guy Teugels at the MRAC, Didier Paugy of the MNHN and to Melanie Stiassney of the AMNH for their invaluable help in identifying the fish and compiling the list of species.

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